Prince George Forest Region

Forest Resources & Practices Team

March 1997
Note #PG-10

Sitka alder may compete with conifers, but it benefits site productivity by fixing nitrogen.

FOREST RESEARCH NOTE

# Ecological Roles of Sitka Alder in a Young Lodgepole Pine Stand

*by Paul Sanborn, Rob Brockley[1] and Caroline Preston[2]*

## Introduction

Sitka alder (*Alnus crispa* ssp. *sinuata*) occurs widely across British Columbia from Vancouver Island and the mainland coast, through much of of the interior west of the Rocky Mountains. In the Sub-Boreal Spruce (SBS) zone, and elsewhere in the central and southern interior, this species is a common shrub component of forest understories. In young conifer stands, pre-existing alder clumps usually regrow rapidly and new plants may establish if suitable mineral soil seedbeds have been created by logging or site preparation.

Foresters are concerned about potential competition between Sitka alder and managed conifer species, so field experiments have examined the effects of vegetation management treatments on conifer performance. For lodgepole pine (*Pinus contorta* var. *latifolia*), Simard (1990) found that diameter growth was reduced when alder cover values crossed a rather wide threshold of 10-35%. This estimate was refined by Simard and Heineman (1996), who detected pine growth responses when alder was reduced from 22% to 15-18% cover.

Despite this concern with competition, we need to recognize the benefits of Sitka alder to site fertility. As a nitrogen-fixing species, through its root symbiosis with the actinomycete *Frankia*, it provides a natural mechanism to restore nitrogen lost by wildfire, harvesting impacts, or site preparation. Previous studies on coastal sites have estimated N-fixation rates ranging from 20 kg/ha/year (Binkley, 1981) to 150 kg/ha/year (Heilman and Ekuan, 1982). In less productive interior forests, rates are likely to be considerably lower — the only published study (Mead and Preston, 1992) estimated a rate of approximately 6 kg/ha/year for a site near Cranbrook. Numerous studies (e.g. Brockley, 1996) have documented widespread N deficiencies in interior B.C. lodgepole pine forests, so even modest rates of N-fixation by Sitka alder may help to maintain long-term soil productivity.

*Photo 1. Initial (1994) Sitka alder cover prior to installation of experimental treatments.*

## Objectives

To improve our knowledge of Sitka alder and its role in interior forests, we began this study in 1994 to address two main questions:

(1) What is the contribution of Sitka alder to the N budget of interior lodgepole pine forests?

(2) Is the benefit of vegetation management treatments for early lodgepole pine growth offset in the long- term by the loss of N-fixation?

## Study Site

Our search for study sites concentrated on the SBSdw3 subzone where mesic and submesic sites commonly have Sitka alder as a major shrub component (DeLong *et al.*, 1993). The chosen site is 55 km SW of Prince George in the Vanderhoof Forest District, at approximately km 4 on the Bobtail-Berta Forest Service Road (Figure 1)(Table 1). Most of the alder at the study site originated from regrowth of clumps originally present in the pre-logging understory (Photo 1). Although seed production is abundant, we have observed very little establishment of new alder plants due to the lack of suitable seedbed after the winter logging in 1987.

## Study Design and Methods

### Main Treatments

Within the 50 hectare opening, we found enough areas of relatively uniform alder cover to accommodate 12 experimental plots (25.28 x 31.60 m), allowing 3 replicates of 4 alder removal treatments in a completely randomized design (Table 2). Pine was thinned to 1000

*1. Kalamalka Research Station, Ministry of Forests*
*2. Pacific Forest Centre, Canadian Forest Service*

stems per hectare in all treatments. Although the initial average alder density exceeded 4000 clumps per hectare, its distribution was too patchy to permit a treatment with more than 2000 uniformly-spaced clumps per hectare. However, we preferentially removed smaller clumps, so in the latter treatment, we were left with a final alder cover of 38.2% — well above the threshold where competitive effects on pine should be occurring.

Pine and alder thinning was done manually in June-July, 1995, with glyphosate applied to the cut alder stems. Only minor retreatment was needed in 1996 to control sprouting.

Initial measurements of the pine and alder remaining after treatment showed a consistently greater height for the shrub species (Table 2). Remeasurements will occur at 3-year intervals.

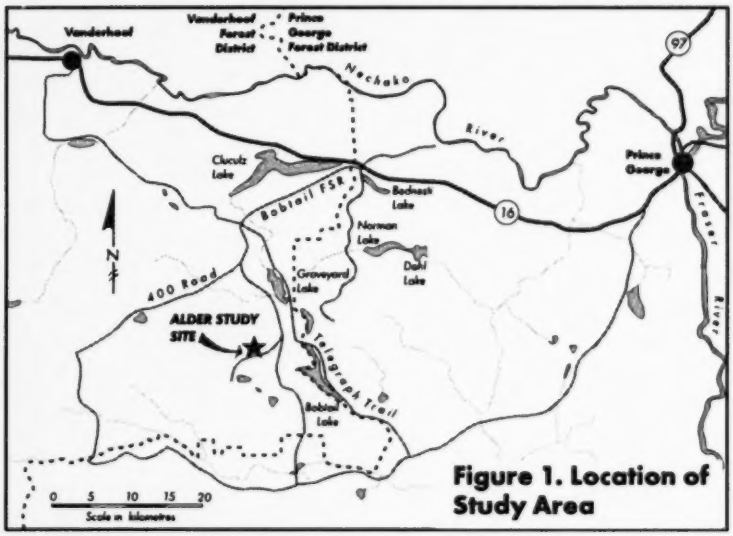


**Figure 1. Location of Study Area**

## TABLE 1: Site Characteristics

- SBSdw3 subzone
- Brunisolic Gray Luvisolic soils, formed on silt loam - loam morainal deposits with 40% coarse fragments
- elevation 1030 m
- W aspect, 5-20% slopes
- logged 1987
- naturally regenerated to lodgepole pine (average 10,430 stems per hectare)
- initial alder cover: 51% (4100 clumps per hectare)

## TABLE 2: Alder Removal Treatments (1000 stems/ha lodgepole pine in all treatments)

| Treatment | Alder Density (clumps/ha) | Alder Cover (1996)[%]* | Alder Height (1995)[m]* | Pine Height (1995)[m]* |
|---|---|---|---|---|
| 1 | 0 | n/a | n/a | 1.57 (0.44) (n=108) |
| 2 | 500 | 10.4 (1.3) (n=3) | 1.88 (0.30) (n=54) | 1.22 (0.42) (n=108) |
| 3 | 1000 | 20.4 (1.8) (n=3) | 1.87 (0.29) (n=108) | 1.50 (0.40) (n=108) |
| 4 | 2000 | 38.2 (1.3) (n=3) | 1.81 (0.38) (n=229) | 1.53 (0.39) (n=108) |

*mean (standard deviation) (sample size)

## Nutrient Cycling

### *(1) Nitrogen-fixation*

After considering the range of methods for estimating N-fixation (see page 4), we adopted two: a long-term mass balance, and $^{15}N$ isotope dilution. For estimating initial soil nutrient pools, we sampled forest floors and mineral soils (0-20 cm) at 15 points in each plot, along with measurements of forest floor mass and mineral soil bulk density.

For our $^{15}N$ isotope dilution experiment, we established 14 "mini-plots" of 2-m radius, centred on alder clumps and containing several non-N-fixing shrub and herbaceous species, in addition to lodgepole pine seedlings. We applied 0.2 g $^{15}N/m^2$ as highly-enriched ammonium sulphate, a rate which has been shown to provide a long-lasting labelling effect (Mead and Preston, 1992). This method will only allow us to estimate the proportion of the N in alder tissues which came from the atmosphere, so biomass production has to be measured separately. We intend to sample several mini-plots destructively after each of the following intervals: 2, 7, and 15 years. This will allow us to track N-fixation rates as the developing pine canopy begins to shade the alder shrub layer.

### *(2) Litterfall Sampling*

To estimate the organic matter and nutrient return via litterfall, we installed litter traps in the the highest density alder retention treatment (2000 clumps/ha).

### *(3) Litter Decomposition*

Alder leaf litter is usually much more nutrient-rich than pine needle litter, we wanted to determine if mixing these contrasting materials will affect litter decomposition rates. In October, 1996, we constructed and installed 3 types of mesh litterbags in the highest density alder retention treatment: pure pine needles, pure alder leaves, and a 50:50 mixture. Bags will be recovered twice yearly for 4 years to determine mass loss and changes in chemical composition. We used materials and methods identical to those in the Canadian Intersite Decomposition Experiment, so our measured rates of decomposition can be compared to a national database.

## Early Results

### *Initial Nutrient Pools*

When combined with forest floor mass and mineral soil bulk density data, initial element pool sizes can be calculated (Table 3). Similar data are surprisingly scarce for interior B.C., but these values are within the

range of those observed at the 3 SBS sites of the Long-Term Soil Productivity Study (Ministry of Forests E.P. 1148).

The location of each of the 180 sampling points was classified according to proximity to alder clumps: either beneath an alder canopy, or between clumps. Grouped in this way, we found significant enrichment in N and other nutrients in forest floors beneath alder clumps (Table 4). We do not know how much of this difference can be attributed to accumulation since the 1987 harvesting. No alder-related soil chemical differences were found in the mineral soil, suggesting that any effects of our treatments will likely be detected first in the forest floor.

### *Nitrogen-fixation*

Following the June 13th application of the $^{15}N$ tracer, we observed a rapid labelling of the foliage of the non-N-fixing species (Table 5). In contrast, the alder leaves showed only a modest increase in their $^{15}N$ content, confirming that this species is deriving almost all of its nitrogen from the atmosphere, rather than from soil sources. Note also the wide range in the strength of labelling in the non-N-fixing species, which demonstrates the importance of using more than one control species in isotope dilution studies.

### *Litterfall*

Chemical analysis of the materials used in the litterbags demonstrated the consistently higher nutrient concentrations in the alder leaf litter (Table 6).

## Allied Work

### *Mycorrhizal Studies*

Greenhouse pot experiments in Sweden have demonstrated that direct transfer of fixed N can occur from alder to lodgepole pine seedlings via mycorrhizal fungi (Arnebrant *et al.*, 1993). Detecting such transfers in the field is much more difficult, but a necessary first step is to identify the fungi which might be colonizing both species. Work in progress at UNBC by graduate student Aniko Varga, supervised by Professor Hugues Massicotte, is using morphological and molecular criteria to characterize the mycorrhizal fungi on the alder and pine roots at this site and in adjacent mature stands.

### *Alder and Soil Rehabilitation*

The extensive and dense alder cover at this site makes it a convenient seed harvesting area, and a large quantity was gathered by contract seed collectors in 1994. Seedlings produced from this seedlot by Dr. Chris Hawkins at the Red Rock Research Station are being used in soil rehabilitation studies at the Aleza Lake Research Forest. To ensure seedling colonization by the N-fixing symbiont *Frankia*, we sampled fresh root nodules at our site, and prepared a suspension which was irrigated onto our seedlings in the nursery. This simple technique produced satisfactory inoculation on more than 2/3 of the seedlings.

## Acknowledgements

Initial support for plot establishment was provided by FRDA II and the Prince George Forest Region. Forest Renewal B.C. is supporting the continuing silvicultural and nutrient cycling components of this study through Projects HQ96157 and OP97077-RE. We thank Christine Unghy, Frank Rowe, John Stigger, Megan D'Arcy, Alena James, James Froese, Brenda Roosdahl, Luke Ferdinands, Luke Stiles, and Joel Woode for their assistance in the field and lab, and Kevin McCullough (CFS) and the Glyn Road Lab (MoF) for analytical services.

**TABLE 3: Initial Soil Elemental Pool Sizes (kg/ha)**

| | Total C | Total N | Mineralizable N | Total S |
|---|---|---|---|---|
| Forest Floor | 32,392 | 769 | 29 | 57 |
| Mineral Soil (0-20 cm) | 22,640 | 1,181 | 35 | 70 |

**TABLE 4: Alder Effects on Forest Floor Nutrient Concentrations**

| | Sampling Location | |
|---|---|---|
| Nutrient | Under Alder* (n = 95) | Between Alder* (n = 85) |
| Total N (%) | 1.24 (0.38) | 1.05 (0.30) |
| Mineralizable N (ppm) | 527 (258) | 410 (166) |
| Total S (%) | 0.090 (0.024) | 0.081 (0.020) |
| Available P (ppm) | 121 (51) | 98 (45) |
| Extractable Ca (ppm) | 3731 (915) | 3208 (740) |
| Extractable Mg (ppm) | 696 (197) | 597 (157) |

**mean (standard deviation)*

**TABLE 5: $^{15}N$ Isotope Dilution Experiment - Initial Foliar Uptake**

| | Atom %$^{15}N$* | |
|---|---|---|
| Species | Pre-Application (6/13/96) | Post-Application (8/20/96) |
| Sitka Alder (n = 14) | 0.36734 (0.00031) | 0.39299 (0.01344) |
| Lodgepole Pine (n = 14) | 0.36711 (0.00063) | 0.60076 (0.06049) |
| Black Huckleberry (n = 9) | 0.36709 (0.00051) | 0.80325 (0.12913) |
| Birch-leaved Spirea (n = 5) | 0.36742 (0.00038) | 0.54803 (0.04660) |

**mean (standard deviation)*

**TABLE 6: Initial Nutrient Concentrations in Litterbag Foliage Materials**

| | Nutrient Concentration (%)* | |
|---|---|---|
| Element | Alder | Pine |
| N | 1.47 (0.01) | 0.56 (0.05) |
| P | 0.357 (0.025) | 0.063 (0.001) |
| S | 0.077 (0.002) | 0.041 (0.002) |
| Ca | 1.309 (0.028) | 0.708 (0.037) |
| Mg | 0.256 (0.005) | 0.078 (0.010) |
| K | 1.096 (0.051) | 0.108 (0.003) |

**mean (standard deviation); n = 3*

## Methods for Estimating Nitrogen-Fixation Rates in Forestry Field Research

### *(1) Mass Balance*

The accumulation of N over time in the vegetation and soil components of a stand should give a minimum estimate of N-fixation rates. However, the high spatial variability of soil properties may make all but the most rapid rates of N-fixation undetectable, except over long time periods and after very intensive (and expensive) sampling. If N losses occur to the atmosphere or by leaching, the measured N accumulation will underestimate fixation rates.

### *(2) Acetylene Reduction Assay*

This technique can be used to estimate the activity of the enzyme system responsible for N-fixation in the root nodules of symbiotic N-fixers such as alder. In biological N-fixation, the enzymes that break the triple bond in $N_2$ can make the same transformation in acetylene ($C_2H_2$), reducing it to ethylene ($C_2H_4$), which is easily measured by gas chromatography. This method is well-established in agricultural research, but its main limitation in forestry is that a stand-level estimate of root nodule biomass is required. This is a challenging proposition for extensive shrub root systems in stony soils!

### *(3) Stable Isotope Methods: $^{15}N$ Natural Abundance*

The heavier stable isotope of nitrogen, $^{15}N$, makes up only 0.3663% of the N in the atmosphere — almost all of the rest is $^{14}N$. In soils, a variety of processes in the N cycle gradually leads to a slight enrichment in $^{15}N$ relative to its abundance in the air. This difference is only a few *parts per thousand*, but it is readily detected with modern mass spectrometers. If an N-fixing plant is growing next to a non-fixing species with similar rooting habits, it should be possible to use the relative $^{15}N$ natural abundance levels in their tissues to estimate how much of the N in the fixing species came from the atmosphere. The N-fixing species should have $^{15}N$ levels very close to those in the atmosphere, while the non-fixing plants will be slightly enriched in $^{15}N$, reflecting their reliance on N derived from the soil. If this difference is observed, then we can estimate stand-level N-fixation once biomass production by the N-fixer is measured.

Unfortunately, many factors can complicate this intuitively appealing method, and we found quite ambiguous results for our site — alder actually had a *higher* $^{15}N$ natural abundance than several non-fixing species, relative to atmospheric concentrations! This was exactly the opposite to what we would have expected.

### *(4) Stable Isotope Methods: $^{15}N$ Isotope Dilution*

This is similar in principle to the previous method, except that we accentuate the difference between the fixing and non-fixing species by adding to the soil a small amount of an N compound which has been highly enriched in $^{15}N$. The non-fixing control species will become highly labelled, while the fixing species will take up very little of the tracer because it relies on atmospheric N. As with the natural abundance method, it is still necessary to measure biomass production to estimate stand-level N-fixation rates. The main disadvantage of this method is the cost of $^{15}N$ — currently over $200 per gram.

## References


Arnebrant, K., H. Ek, R. D. Finlay, and B. Söderström. 1993. Nitrogen translocation between *Alnus glutinosa* (L.) Gaertn. seedlings inoculated with *Frankia* sp. and *Pinus contorta* Doug. ex Loud seedlings connected by a common ectomycorrhizal mycelium. *New Phytol.* **130**: 231-242.

Binkley, D. 1981. Nodule biomass and acetylene reduction rates of red alder and Sitka alder on Vancouver Island. *Can. J. For. Res.* **11**: 281-286.

Brockley, R.P. 1996. Lodgepole pine nutrition and fertilization: a summary of B.C. Ministry of Forests research results. *FRDA Report 266.* Canadian Forest Service / B.C. Ministry of Forests.

DeLong, C., D. Tanner, and M. Jull. 1993. A field guide for site identification and interpretation for the southwest portion of the Prince George Forest Region. *Land Management Handbook Number 24.* B.C. Ministry of Forests. 290 p.

Heilman, P. and G. Ekuan. 1982. Nodulation and nitrogen fixation by red alder and Sitka alder on coal mine spoils. *Can. J. For. Res.* **12**: 992-997.

Mead, D. J. and C. M. Preston. 1992. Nitrogen fixation in Sitka alder by $^{15}N$ isotope dilution after eight growing seasons in a lodgepole pine stand. *Can. J. For. Res.* **22**: 1192-1194.

Simard, S. 1990. Competition between Sitka alder and lodgepole pine in the Montane Spruce Zone in the southern interior of British Columbia. *FRDA Report 150.* Forestry Canada / B.C. Ministry of Forests. 26 p.

Simard, S. and J. Heineman. 1996. Nine-year response of lodgepole pine and the *Dry Alder* complex to chemical and manual release treatments on an ICHmk1 site near Kelowna. *FRDA Report 259.* Canadian Forest Service/ B.C. Ministry of Forests. 19 p.



**For further information**

Paul Sanborn, Research Soil Scientist
BC Ministry of Forests, Prince George Region
1011 - 4th Avenue,
Prince George, BC, V2L 3H9
Phone (250) 565-6100
Fax (250) 565-4349
email: psanborn@mforØ1.for.gov.bc.ca